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The Stanford Center for Radar Astronomy is a joint venture of groups at Stanford University and SRI who share an interest in the application of radar and other radio techniques to a broad range of problems. We are concerned with the scientific study of our planet and the whole of the solar system, and with technological and other developments for improved communications and related national space-application programs. This work is conducted with support from NASA and other federal agencies and involves graduate student research assistants working toward advanced degrees. Studies involving the propagation of radio waves between ground terminals and a probe in space (bistatic radar astronomy) have received special emphasis. This technique has been successfully applied to studies of the earth's ionosphere, the cislunar medium, the interplanetary medium, the solar corona, the atmospheres of Mars and Venus, and the surface of the moon.

The complex nature of radio and radar experiments and development requires expertise in a variety of subject areas. For example, bistatic-radar experiments conducted with space probes require a familiarity with orbital mechanics, optimal signal detection theory, numerical analysis, spacecraft instrumentation, and electromagnetic propagation and scattering theory. In addition, all relevant information on the region of study (such as a planetary atmosphere) obtained from other sources must be understood in the context of what the radar or radio investigation can contribute. Equally diverse disciplines are required for the other

experimental, theoretical, and applications areas mentioned above. As a result the Center is made up of individuals of highly varied backgrounds and specialized abilities, and graduate students working toward dissertations on a broad range of subjects. However, the unifying principal underlying all the work of the Center has been, and remains, research into physical phenomena of the space and planetary environments, and other related applications of the techniques of radio science and technology.

The Center has been supported by both grant and contract sources. Projects, such as the Pioneer 6-9 or Apollo 14-16 experiments, have been carried out on a contract basis, following the acceptance of the experiment by the sponsoring agency (usually NASA). Some grants for definite purposes have also been obtained, and both grants and contracts have been awarded for individuals in the Center to participate in the mission definition and implementation phases of the radio teams chosen for Venus-Mercury, Viking, and Jupiter-Saturn missions. However, the NASA sustaining grant has provided the fundamental nucleus from which other work has evolved.

At the Center, the sustaining grant (NGL 05-020-014) covers a broad spectrum of activity in space sciences. During the past year the grant has been used for support in three general areas. (1) Theoretical and experimental efforts of certain graduate student research assistants and staff members are supported by the grant, in a number of areas of space science or applications which may not have specific connections with any NASA flight project. (2) The efforts of some members of the Center are supported, at least in part from the grant, in areas which are either expected to develop into future separate projects, or which are peripheral

to the main thrust of other present projects (such as a separately-funded flight project), but which, nevertheless, show promise for possible future developments in that field. (3) Of vital importance to the activities of the Stanford Center for Radar Astronomy is the role of the grant in providing continuity and the ability to respond quickly to new opportunities, and in helping to provide for support equipment and support capabilities for the benefit of all of the space activities of the Center.

In our Status Report number 17 of last year, dated July 1971, we used the example of the development of the radio occultation method for the study of planetary atmospheres to illustrate both the breadth and the unifying theme of the work at the Center. This example includes features related to advancing atmospheric science and electromagnetic theory, developing new techniques for scientific measurement and analysis, developing and using spacecraft and ground-based instrumentation for the studies, planning and conducting supporting laboratory experiments, studying applications of the occultation technique for investigations of the terrestrial atmosphere for weather prediction, defining relationships of the occultation studies to other programs at the Center for earth atmospheric investigations, and planning and participation in radio-science investigations for future planetary missions.

Another example of this type is provided by the bistatic radar technique for the study of planetary surfaces. It is at an earlier stage of development than the occultation technique for the study of planetary atmospheres, but recent advances based on theory plus the results of the Apollo 14-16 measurements lead us to predict that it will have a similar impact on future planetary studies. At the time of the first proposals for the surface studies, it was known that there were several results

of importance that could surely be gained from good measurements. However, theory has advanced in pace with the measurements, and as was the case for the atmospheric studies, the surface experiments are proving to be much richer in information than could have been predicted before the experiments. In other words, the state of the science is advancing with the state of the art for these surface investigations. It should also be noted that first bistatic radar experiments are being conducted for the moon, where relationships of the results with a great number of other experiments are being determined. Thus when the technique is extended to the planets, "ground-truth" results will have been established so that the measurements may take on even greater significance.

In addition to the above, we believe that technological and engineering interplay with the scientific investigations is of great importance to the success of the Center. For example, the Center has provided flight hardware for the Pioneer 6-9 and Mariner V dual-frequency experiment and has been instrumental in helping in the decision to change the NASA Deep Space Net telecommunications to a dual-frequency system that will greatly improve radio science experiments and at the same time provide better communications and better tracking. We hope to be able to continue a strong program involving our radio and radar facilities, our ability to provide flight hardware, and continuing field and laboratory studies involving systems and instruments built by the Center for both scientific experiments and communications and earth-applications programs.

SECTION A

Faculty, Staff, and Student Contributions

G. L. Tyler

Radar Scattering

The lunar experimental work described in the last several reports has evolved into the data analysis phase. Experimental and analytical studies of scattering from the sea are continuing. Preliminary studies of a Saturn ring occulation experiment is underway in anticipation of an MJS proposal.

Bistatic-radar experiments were conducted on three Apollo missions, Apollo 14, 15 and 16. These experiments have resulted in unique data sets consisting of observations of forward-scatter from the lunar surface at two wavelengths (13 and 116 cm). Two scientific papers, describing results from Apollos 14 and 15, have been prepared and are in press (Parker and Tyler, Tyler and Howard). This activity has been marked by a substantial increase in our understanding of bistatic-radar data and its quantitative relationship to the statistical parameters of the lunar surface. In summary, the following types of problems may be attacked with this technique.

a) Surface reflectivity: The surface reflectivity of planetary material may be determined with very little error (~1%) due to uncertainties in surface shape factors. A principal difficulty in the past has been the separation of shape and reflectivity. This determination must be considered a fundamental quantity in remote sensing of planetary surfaces.

b) Vertical structure: Dispersive, i.e., multiple frequency, measurements of a), tightly bound the permissable range of models for subsurface structure with depth. In the case of the moon and Mars, electromagnetic vertical structure may be interpreted directly in terms of variations in surface density with depth. Such inferences have been carried out for the moon with good results.

c) RMS slopes: Root-mean-square slopes may be determined directly from bistatic-radar data by simple measurements on the echo spectra. Over particular sets of horizontal scales, the rms slopes are a quantitative measure of surface roughness.

d) Surface height spectrum: Dispersive measurements of rms slopes give the planetary surface height spectrum, within an unknown multiplicative factor. The surface height spectrum is directly related to the processes that created and modified that particular surface.

e) Surface slope distributions: Probability distributions of planetary surface slopes may be obtained indirectly by inversion of bistatic-radar spectra. These distributions give the probabilities of finding slopes of a particular value within a specified range of surface scales. As such, the distributions represent a much more complete description of the surface than the simple rms slopes.

At the present time, and over the period of the next year, we are continuing with the analysis of lunar data and will be considering future planetary applications of the bistatic-radar technique. Emphasis for future experiments will be on the planet Venus.

Studies of scattering from the sea are continuing in collaboration with Scripps Institute. This work makes direct use of experimental techniques developed in the lunar bistatic-radar work. Both monostatic and bistatic-radar experiments have been undertaken. The monostatic work utilizes equipment, transmitter and receiver, constructed at Stanford for this work (Tyler, Faulkerson, Peterson, Teague, 1972). The bistatic experiments utilize transmissions from LORAN A stations in various locations (Peterson, Teague and Tyler, 1970). This work involves fundamental inquires into the nature of scattering from the sea and into the relationship of directional wave-height spectra to the driving winds. In the long term, it is hoped that these studies will evolve into techniques for remote sensing of winds by measurement of the sea wave-height spectra, either from the land or from satellites.

There are now four Ph.D. students actively working in the area of scattering theory and experiment. We are quite hopeful that with their help there will be continued and sustained progress in this work and its lunar and planetary applications.

M. J. Sites

Development of an Unmanned Geophysical Observatory for use in the Antarctic

The Unmanned Geophysical Observatory (UGO) at McMurdo is now into its seventh month of continuous operation with the INTELSAT system. All components are functioning and all telemetry readings are well within their nominal ranges.

During this period the UGO has operated during two intense storms with winds measured in excess of 130 MPH at the observatory site. The only interruptions of service have occurred during power outages at McMurdo Station, which supplies power for UGO operation during the test period.

Error rates are presently approximately 1×10^{-5} and have remained at this level since switch-over to INTELSAT IV from INTELSAT III. In addition to error rate measurements, the received carrier level at Jamesburg was monitored for approximately three weeks beginning 1 May. No variations in level were noted except for a period during the week of 17 May, when both long (>5 min) and short period variations were recorded. The long period variations are on the order of 1 dB loss with respect to the usual received level; the short period variations show both enhancement and loss on the order of 1 dB. However, the duration is very short (<10 sec). Examples of undisturbed, long term variations, and short term variations are shown in the figures.

Antarctic data is recorded continuously, except during McMurdo power outages, telephone line outages, and system maintenance.

The Stanford University supplied receiving equipment at the Jamesburg, California earth station also continues to operate well, with no failures since late January 1972.

Because of the high cost of operating the command link from Jamesburg to the Antarctic, no commands have been sent since the end of the January test period. However, telemetry readings of noise AGC levels and microwave source loop stress voltages indicate that the command receiver remains operational.

Calvin C. Teague

Bragg Scattering Probing of Sea State

Analysis of the LORAN data from the Hawaii experiment of last year is continuing. The transformation from delay-doppler space to wave number space, which is complicated by the necessity to include the ship velocity, is presently being handled through a least-squares data fitting procedure. Although this procedure is conceptually straightforward, practical difficulties have arisen due to the sheer magnitude of the data. In general, large matrix manipulations are required, and a typical matrix size is 160 by 160. An initial estimate of the directional spectrum covering a full 360° has been obtained. However, it appears that this estimate may be considerably in error, due to incorrect assumptions about the ship velocity, or by noise in the data. It is also possible that conditions were not stationary over the observation time, since four different runs were averaged together, covering a period of about three hours. From the work done so far, it appears possible to obtain estimate of the ocean-wave spectrum by this technique. However, if the experiment were to be repeated, much better measurements of the ship velocity (including drift) should be obtained, as this would greatly simplify the inversion procedure.

The investigation of the second-order effects at 30 MHz is continuing. The radar system has been upgraded with the addition of a new power amplifier. Observations using the three element ground plane yagi antenna have been made on five different occasions along the California coast, three of which were supported by simultaneous observations with the Scripps tilt buoy and by observations of LORAN A echoes. Although the details of the spectra of the received signals vary from experiment to experiment, the general characteristics remain the same. The central, first-order Bragg line is always broadened considerably beyond the frequency resolution of the experiment. This effect may be due to the effects of surface currents. However, sideband energy beyond the broadened first-order line is also present, often containing as much as 50% of the total echo energy. In some cases, it is of the general form predicted by Barrick (1972); in other cases, it does not fit any of the published predictions. The spectrum is usually non-symmetrical about the Bragg line. A null is often observed close to the Bragg line, apparently corresponding to a low-frequency ocean-wave spectral cutoff. In several instances, a well-developed swell was noted breaking along the shore, and its period was determined by a watch. This period corresponds with the spacing of discrete lines from the first-order line, indicating that indeed second-order modulation is taking place, as suggested by Hasselmann (1971). One feature which was not predicted but which has been noted on several runs is the similarity between the sideband structure of the approaching and receding Bragg lines. This similarity resembles a frequency translation from one to the other, rather than a reflection about zero doppler shift. Efforts are currently under way to correlate the radar observations with the wave data from the Scripps buoy, and to make more detailed comparisons with Barrick's predictions.

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Jeremy A. Landt

Characteristics of Dense Solar-Wind Disturbances

The solar wind is the electrically neutral mixture of electrons and positive ions (mostly hydrogen) that flows radially out from the sun at high speed. In recent years, knowledge of the solar wind has increased rapidly, but few observations have been reported concerning the geometries of large-scale solar-wind disturbances that are known as blast waves, driven waves, and colliding streams. These and other disturbances characterized by large increases in density (solar-wind storms) have been investigated through comparisons of single-location measurements to the average of the electron density obtained by radio signal delay measurements along a radiopath between the Stanford campus and interplanetary spacecraft.

Previous studies indicate that blast and driven waves should have broad spherical structures, and this has been confirmed for some events. Shapes of other solar-wind storms have been derived, among which a new class of spatially limited storms was identified; these structures contained regions with densities greater than any observed in the broad storms. Mechanisms involved in the confinement and deceleration of

disturbances were examined, and it was determined that the ram pressure may be responsible for some of their properties. Several possible explanations have been postulated for the observed spatial relationships between dense storms and colliding streams.

A causal relationship between solar-wind storms and certain types of radio-noise bursts from the sun has been proposed and is supported by recent studies of solar-wind storm properties. When storm geometries were ordered by the longitude of solar flares that were accompanied by radio-noise bursts, deviations from the expected pattern were observed. It is possible that nonradial ejection of material can originate from flare sites and that storm geometries can be distorted because of inhomogeneities in the velocity and density of the undisturbed wind. It was found that the size of a storm is approximately in inverse proportion to its density.

Essam Marouf

Bistatic Radar for Study of Planetary Neutral Atmospheres

Bistatic radar has been successfully applied to study the neutral atmospheres of the inner solar system. For example, in the case of the planet Venus, the detailed analysis of Mariner 5 radio occultation experiments showed two separate systems of clouds may exist. In the region extending from the visible clouds down to approximately 58 Km from the surface possible water-vapor mixing rations, temperature, and temperature-lapse rate make water and ice clouds possible. On the other hand, the microwave absorption profile measured suggests the existence of condensibles in the lower region of the atmosphere (50 to 35 Km above the surface). Consistent models of clouds containing such condensates pose a very challenging problem. This problem is under study.

Extension of the basic theoretical study to include propagation through the atmospheres of the planets of the outer solar system is now being considered. Both the bending and the total amount of signal loss of a radio frequency beam probing the massive atmospheres of Jupiter and Saturn will be studied in view of the existing engineering models. The study will lead to the approximate determination of the levels of atmospheres that can be probed by the radio beam before either the beam is largely absorbed or the condition of super-refraction is reached.

Propagation to a spacecraft which is occulted by the Rings of Saturn is also under study. The problem is of a somewhat different nature than the previous ones. Scattering by a slab consisting of a random collection of many bodies is the model used in such a study. The sizes of the bodies in the different systems of rings as well as the electrical properties of their material are still open questions and many models have to be investigated to have more informative results. An approximation is used first to simplify the scattering problem and allow more insight. Then, refined analysis which takes into consideration the effects of multiple scattering will be possible. The analysis should also include study of the inversion problem, namely, the reconstruction of some reasonable models based upon the measured effects on the probing radio signal.

It is hoped that the outer solar system study will be helpful in planning for the future Jupiter-Saturn missions.

R. A. Simpson

<u>Monostatic Radar Studies of the Moon</u>

A program for studying the leading edge of monostatic radar echoes from the moon has been proposed and discussed in earlier status reports. Data are currently available from 25 MHz to 2287.5 MHz (some with bistatic geometry) for comparison of scattering at different frequencies. During the past six months interest has centered almost exclusively on the L-Band (1290 MHz) monostatic data collected in 1970. A summary of this most recent work and preliminary conclusions follows.

1. Analog recordings of the L-Band echoes have been sampled, edited and stored on digital tape. These prime data give information at the leading edge, from several milliseconds after the leading edge, and during periods when only system noise was present. Observations were made on one day when the sub-radar point was near the center of Sinus Medii and on two days when it was about 7° on either side (southeast and northwest) of the first. The results shown distinct shapes of the echo on each of the three days and, although the statistics are not overwhelmingly in our favor, lead us to infer we are scattering from a different type of terrain each run.

2. Because the signal in each range bin of an echo is the sum of a large number of random phasors, the range contributing the maximum power to the echo will jump from bin to bin as the moon librates. By assuming a particular model, one can predict the relative frequency with which bins have the maximum signal. Histograms for both data and theory have been produced and we are now concentrating on relating the shape of the histograms to probability distribution functions for surface slopes.

3. Given a particular model and knowledge of relative motion between the radar and surface it is also possible to isolate the leading edge bin and relate its libration modulation spectrum to the surface slope distribution function, $p_s(s)$. This function can only be inferred over a few degrees because of the finite areal coverage of the first range gin. Nevertheless, an independent check over this limited interval would be helpful and is being pursued.

4. Preliminary estimates of unidirectional (measured along only one of the horizontal coordinates) root-mean-square slopes at L-Band were on the order of 5^{o}. Variations in the echo shape from day to day imply other values at other subradar points, but 5^{o} continues to look reasonable as a typical slope. We feel this is significant since 5^{o} falls at the low end of the range reported by other observers and agrees more closely with bistatic estimates of slope than other monostatic results. Reasons for this discrepancy are not entirely clear.

Study of graded dielectric boundaries (i.e., boundaries over which E(x) is a more or less smooth function of x) and electromagnetic reflection therefore has continued, though with slightly less intensity than was indicated in the last report. Most work has involved models which might explain anomalous results of dual-frequency bistatic experiments (being funded separately) and has been only marginally successful in that respect. Current efforts are directed toward consolidating the L-Band information and filling in such theoretical and processing gaps as may exist.

Robert Wang

Television Source Data Compression

Data compression is construed to be the next step in the art of efficient communication. It is that class of data source encoding techniques that uses the very essence of the source to achieve bandwidth savings in the overall system. Since the characteristics of the data source provide the means for such savings, it becomes imperative that the useable characteristics of the source be describable in tractable terms.

A review of the literature is sufficient evidence that the television video (pictorial) source has received a giant share of the attention of the workers in the field of data compression. Unfortunately, no universally satisfying model of the source has been devised that can aid theoreticians and practitioners of picture data compression in evaluating their results. The need is great but published attempts are scanty and limited. The effort has been to design a model to the following six criteria:

1) Satisfy the needs of data compression systems designers.
2) Obey existing published emperical data on television pictures and be non-stationary.
3) Tractable enough to be useful in theoretical studies.
4) General enough to be non-scan pattern dependent.
5) Pliable enough to allow future updating and improvements as new data come to light.
6) Should suggest new data compression directions and supply a means for understanding the source better.

Approaching the problem with these guidelines in mind, the television video source is modeled as a vector random field with a three-dimensional index space. This random field is specified through postulates that characterize the sample function (pictures and sequences of pictures) space. By using this approach the emphasis is on practicality rather than mathematical elegance.

Compression ratio, which is defined as the ratio of the number of bits needed to reconstruct the data at the receiver of a communication without any compression scheme to that required after a data compression algorithm has been used has been the figure-of-merit of these systems from the start. The compression ratio of the floating-aperture predictor and edge encoder (two picture data compression schemes) have been derived in terms of the picture model parameters and evaluated to show one way of using the model. The generalized model is also applied to describe the source of scenic pictures and that of the typewritten page to demonstrate how it can describe very specific sources. With these examples, it has been shown that the model designed by this research has far reaching possibilities. The main thrust, however, is an attempt to shake loose from traditional approaches to the problem that have not proven fruitful and hopefully supplied a model that could seed even better efforts in the future.

The effort in the next quarter is to prepare the results for a report and publish it as a thesis.

V. W. Ramsey

Measurement of Aircraft Trailing Vortices by Acoustic Sounding Methods

In radar astronomy a well-known technique for deducing statistical information about a moving celestial body is to illuminate that body with a monochromatic wave, and then to study the statistical characteristics of the returned, Doppler-shifted signal. The spectrum of this returned signal is suggestively termed the "target fluctuation spectrum". The aim of this project is to mathematically model and to experimentally verify the target fluctuation spectrum of an aircraft wingtip vortex.

At this reporting, an equation for the interaction of an incident sound wave with the turbulent microstructure of the vortex has been derived and solved. The solution is in closed form, but it contains a double integral which does not appear to be tabulated in any available tables. Efforts at changes of variables to transform the integral into tabulated forms have, so far, been unsuccessful. By choosing the proper order of integration, however, the double integral can easily be placed in a form suitable for numerical calculation with ordinary compiler-supplied FORTRAN functions.

A primary feature of this solution (and the reason for the appearance of the untabulated integral) is the generalization of the model to local homogeneity of the turbulence regime. Even this generalization is probably not sufficient for the core region of the vortex. Since the core occupies only a small percentage of the total vortex volume, though, the model is probably a good one. A critical evaluation awaits experimental data.

Carlos Chang Koo

Radio Acoustic Sounding System

The purpose of this research was to derive more useful information from the existing Radio Acoustic Sounding System at Stanford. The frequency of the radio echoes was used to obtain the temperature profile of the lower troposphere. The amplitude of the back-scattered signals contain some valuable information which has been neglected up till now.

It has been calculated that the mean square of the acoustic wave amplitude variation is related to the scale of turbulence of the propagation medium. Therefore from the amplitude and the phase variation of the

scattered radio signals we obtained the scale of turbulence of the atmosphere at various heights, from the ground up to 800 meters.

The scale of turbulence at high altitudes, i.e. above 100 meters, are desired by meteorologists to check various theories of atmospheric diffusion and to enable more efficient design of atmospheric models used for air pollution studies.

Plans are also made to pulse the radio acoustic soundings continuously for a few hours at five second intervals. From those echoes a temperature vs time curve at a fixed height can be made. Using those curves with the aid of a digital computer the temperature spectrum can be found. This spectrum will be the "energy" content of the atmosphere "eddies". From this spectrum the rate of dissipation of the atmosphere turbulence can be found.

Dan Allen

Satellite Communications for Alaska

I am involved with both phases of this project. The first phase summarizes the engineering experiments undertaken over the past year, using ATS-1: teletype, simplex and duplex voice, xerox facsimile, photo-facsimile, and slow-scan TV. Stanford, University of Washington, University of Wisconsin, and University of Alaska are among the participants. This summary will comprise a final report for the first phase.

The second phase examines near-future satellite communications technology as it might be used in Alaska: future satellites (such as ATS-F, Telsat, or several of the proposed U.A. "Domsats"); small ground stations; terminals; program scheduling and content; and the social

impact of such systems upon Alaskan natives. For this second phase, I am mainly involved with computerizing minimum-cost system designs.

The Synchronous Orbit: Optimal Packing, and a Shadow-Cost Value

This is an independent project I am pursuing, which extends previous work, incorporates recent results (such as sidelobe suppression for small-diameter ground antennas), and which attempt to input a dollar value to a unit of this particular electrospace (bps per orbital degree of arc per Hz of bandwidth).

John Albernaz

Development of Low Cost Receiver Systems for Educational Television Reception

During the past six months the work on the 12 GHz receiver system designed for use in direct reception from satellites has been completed. The prototypes were sent to NASA and the final report is due soon.

More work has been done on the problem of utilization of the geostationary orbit. With the increasing number of users of geostationary orbit and with the increasing number of satellites working at the same frequency band a careful assessment has to be made of the position and the separation between these communication satellites in order to avoid a degradation of the quality of service due to interference.

We have shown that the present CCIR (International Consultative Committee on Radio Propagation) recommendations on the antenna characteristics to be used to evaluate the interfering effects between adjacent satellite systems is somewhat conservative. Using the measured characteristics of antennas presently available and antennas designed for the purpose of satellite communication, a substantial improvement in the efficiency of the geostationary orbit may be attained.

Currently we are evaluating techniques for the design of antennas that offer side-lobe radiation control around the equatorial plane only, i.e., the region where the interfering satellite signals will be located. In this application where the unwanted signals are located in a restricted region, the side-lobe control does not need to be achieved for the whole 360^{o} azimuthal range and this fact should be in the designer's mind. Our approach is to place a pair of patches of absorbing material on the reflector surface in order to control the side-lobes around the plane of interest. The results of this work will be available in the near future.

C. Mitchell

Telecommunication Systems

Pursuing the goal of developing methods and data for telecommunications planners, I have determined the costs of terrestrial telecommunications facilities, in detail, and am in the throes of writing a computer program such that for any link distance and any cross-section (i.e., number of telephone channels to be provided by the link) the minimum cost facility may be determined. The length of the period, T, over which this optimization is to occur may be chosen.

The program is based on communications equipment and costs of manufacturers in the Palo Alto area, and on labor and installation costs for "typical" installations of the Pacific Telephone and Telegraph Co. It accounts for the time value of money by using the present worth of annual costs method. It also lists, by year, the capital expenditures that must be made in providing, upgrading, and maintaining the link, so that cash-flow requirements can be determined.

After this program is completed, one of its outputs will take the form of a graph in matrix format. The length, L, of the telecommunications link under study will be given along the abscissa of the graph. The increase in channel demand per year that must be satisfied by the link, YID, will be given along the ordinate. The matrix element designated by any pair of values (L, YID) will contain the least-cost type of terrestrial telecommunications facility that will satisfy these requirements and the present worth of the facility for the whole T-year period.

My next effort will be to develop an equally precise information base for the costs of a satellite system of comparable capability (i.e., T program distribution and telephone network service). The third step will be the development of a model by which these two systems may be compared, to determine the least-cost system for the given set of requirements encompassing many links.

B. Parasuraman

A Hardware/Software Incremental Computing System

In the period since the last report, the study of software interface requirements for incremental computers has been completed, and the results are presented in ref. 1. The outcome of this research has been the development of problem-handling procedures and automatic programming techniques for the real-time numerical solution of differential equations. The target system for the use of these methods is a hardware digital processor operating in conjunction with a suitable mini-computer (ref. 2); however, the results of this study may also be used independently to provide complete program set-up information for systems that utilize digital differential analyzers.

The significant feature of the software package is its user-oriented convenience. Input information consists of the equations under study, initial conditions and solution terminations points. The program returns a complete set of mapping connections and a table of compatible magnitude scales as intermediate output. This information is then processed in the hardware and used to generate the required numerical solutions. The hardware configuration and machine environment are described by E. Schulz in ref. 2.

The incremental computing system can be used for a variety of applications other than direct equation solving. These include: digital function generation, digital filter realizations, digital spectrum analysis, and continuous system simulation. Further research directions are needed to study the application of these techniques to partial differential equations. Such studies would have positive effects in the handling of grid equations in weather prediction and the trajectory equations in ray tracing.

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Eduardo W. Bergamini

Incremental Computation

DDA structures for real time processing and their applications for signal processing and generation are under development. Our recent work has been concentrated in evaluation of error bounds for many processing structures, based on the concept of residue retention analysis. Identification of the sources of processing error has been performed, as well as, explicit ways of quantitatively evaluating the bounds of each particular error, when in open loop configuration. The suitability of such bounds have been confirmed, based on new results of simulation in a general purpose computer. Such bounds are an important tool in practical design of any processing structure employing DDA's of the type we propose. They will give, at least, a qualitative 'a priori' knowledge of the precision and/or accuracy of the incremental computation model that may be under design.

As already noticed, new simulation results were obtained with the main purpose of evaluating the proposed DDA structure performance(s), through the realization of the harmonic equation (y+y = 0) closed loop, a classical procedure for performance evaluation. Consistent results have been obtained within a contiguous set of different step sizes. Also, comparatively amazing consistency was verified with recent results published in the literature of this specialized field.

One of the next steps to be performed in our present work is the development of procedures, i.e., DDA modular and inter-modular characterizations, in order to establish criteria for systematic programming of the proposed structurex, in any sort of application, whenever it is realizable.

A. A. Cristaldo

A Digital Data-Acquisition System for the New South Pole Station

Several research programs are being conducted in the Antarctic. Because of the increasing national interest in these programs, the construction of a new scientific station as close as possible to the geographic South Pole is under way.

An improvement in the quality of data recording and reduction in logistic support will result from the implementation of a digital data-acquisition system (DAS) that will increase the effectiveness of the station by eliminating the present undersirable one-man/one-discipline mode of operation. The amount of human intervention and associated sources of error will be minimized by a relatively high degree of automation.

The design of such a DAS led to the development of a system that can be operated and maintained solely by the resident scientific team at the South Pole. The rigid requirements of high reliability, flexibility and simple operation and maintenance using only available equipment will be met by (1) the adoption of a distributed configuration, (2) implementation of a computer-controlled system that provides versatile on-line/ real-time data-acquisition and control capabilities, (3) adequate level of redundancy at critical points, (4) spare parts readily available both at the component and instrument level and (5) training program for the resident personnel.

J. Mortelmans

An Adaptive Processor

This study concerns itself with the exploration of a new processor architecture which 'in a limited way has the ability of adapting its subprocessor configuration to the problem program at hand. The system consists of a certain amount of hardware which can be configured in different modes. One such mode would be the single processor configuration. It would provide a powerful computer with a very large instruction repertoire for the highly sequential type of program, where little could be gained by parallel processing. The mode with the opposite purpose would provide several independent minicomputers with modest computing power but a high potential for parallel processing. The remaining modes of operation would yield compromises between parallel action and conventional computing power.

The limitation on the range of adaptability depends on the complexity of the system. Presently, only a relatively simple architecture is proposed in order to facilitate its description and analysis.

The electronic hardware switching from one mode to the other requires only a few logic gate delays and therefore can be done easily and quickly. The corresponding software preparation of the data for a change of configuration is, of course, a less trivial problem that will require a lot of attention. It is intended that major hardware aids will be provided to help reorganize the data in a way that will suit the individual configurations.

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